Simple Current-Loop Transmitter Converts PWM To 4-to-20-mA Output

W. Stephen Woodward
University of North Carolina, Marine Sciences, Venable Hall, CB3300, Chapel Hill, NC 27599-3300; e-mail: woodward@.unc.edu

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Over long cable runs, an isolated 4-to-20-mA current loop offers robust noise immunity and tolerance. This characteristic makes it popular for analog data transmission in noisy industrial and process control environments. Unfortunately, the conversion of a digital output to an isolated current-loop signal is a relatively complicated proposition. In addition to the actual signal isolator components, paraphernalia such as multiple floating power supplies and DACs are typically required.

A simpler scheme is used for this circuit *(Fig. 1)*. It's based on pulse-width modulation to implement a cheap but accurate current-loop transmitter. A dual-channel isolator (E1-E2-Q1-Q2) provides galvanic isolation of the PWM input. It uses this input to chop the 1.25-V reference voltage of the LT317AT regulator in response to the 1- to 2-kHz PWM input applied to the E1/E2 LED pair. Phototransistors Q1 and Q2 switch R4 between the top and bottom ends of the R1/R2 current-set resistance.

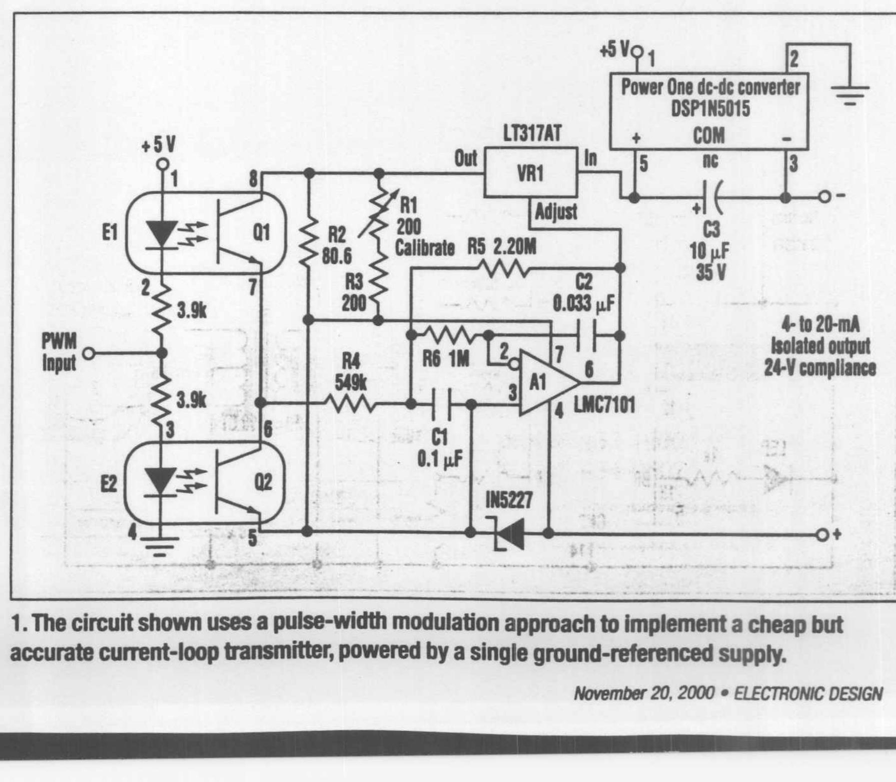
The pulse-width duty factor of the PWM input varies between 0% and 100%. At the same time, the dc component of the isolated analog waveform sourced to R4 varies from 0.25 to 0.0 V relative to A1-pin 3. A1's low-pass, gain-of-four filter extracts this dc portion and applies it to the adjust pin of VR1. This allows the voltage between the VR1 adjust and A1-pin 3 to fluctuate from 1.0 to 0.0 V. As a result, the voltage across the R1/R3 resistance varies from 0.25 V (at a duty factor of 0) to 1.25 V (at a duty factor of unity). Consequently, a 4- to 20-mA current is drawn from the out terminal of VR1 and circulated in the output loop.

The full-scale 20-mA output is trimmed via R1. The impedance of the low-pass filter network is quite high (≈ 3 MΩ). This limits the phototransistor saturation offset to ≈ 1 mV. Meanwhile, the picoamp-level bias current of A1 prevents these big resistors surrounding its summing point from causing significant errors. Relatively long (tens of milliseconds) filter time-constants are needed for adequate ripple reduction. The high-feedback network impedances allow this to be achieved with only modestly sized capacitors.

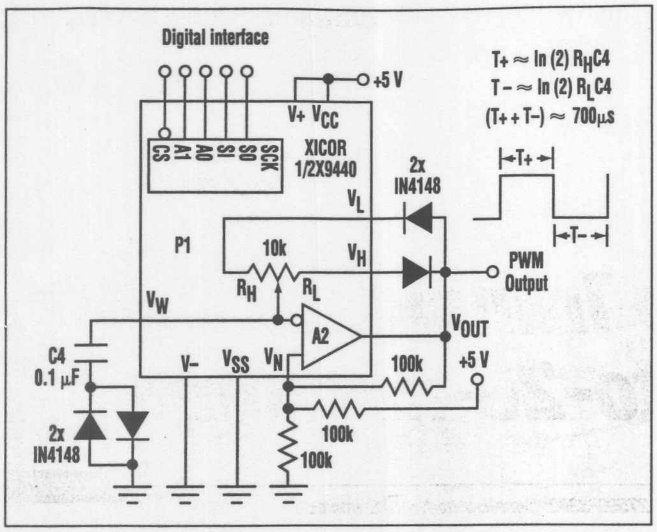
Performance of the resulting current loop is respectable. The 1% guaranteed tolerances of the critical components (VR1, R1, and R2) yield typical accuracies greater than 8 bits. Resolution, differential linearity, and monotonicity are equal to that of the PWM digital waveform—that is, except in cases where the duty factor values are smaller than 0.01% or larger than 99.99%. At these extremes, the control signal may spend less time in the zero or one state than is required by the isolator to completely switch from one rail to the other. This results in a modest increase in differential nonlinearity for this very restricted range of values.

With risetimes less than 100 ms, the settling time to 0.1% is less than 500 ms. The output ripple is less than 0.01% of full scale. If the dc-dc converter is omitted, passive transmitter operation displays a voltage compliance spanning 7 to 45 V. In other words, it ranges from the minimum voltage drop necessary for proper operation to the maximum operating voltage of VR1.

The dependence of the output current upon loop voltage is less than 50 ppm/V over the whole range. This is due to the excellent line regulation behavior of



1. The circuit shown uses a pulse-width modulation approach to implement a cheap but accurate current-loop transmitter, powered by a single ground-referenced supply.



2. A constant-frequency PWM multivibrator published in an earlier IFD is adapted to digital control via the Xicor X9440 dual "smart analog" comparator/potentiometer combination.

VR1. Adding the dc-dc converter enables active transmitter operation with an isolated output compliance of 24 V. All circuit power comes from a single ground-referred 5-V rail.

A number of methods can be used to generate the PWM input. In microcontroller-based applications (e.g., Motorola 68HC12), the on-chip counter/timer hardware can provide a convenient source. Figure 2 illustrates another possibility. This idea uses a constant-frequency PWM multivibrator that was derived from an earlier IFD (*"A New Stable RC Pulse Generator," Feb. 8, 1999, p. 104-106*). That circuit is adapted to digital control via the Xicor X9440 dual "smart analog" comparator/potentiometer combination. The convenience of the X9440's strapless-address SPI interface partially makes up for its somewhat limited (6-bit) resolution.

ifd winners

Paul R. Woods, 3781 Tyler Pl., Corvallis, OR 97330; e-mail: paulw@peak.org.

The idea: *"Amateur Radio Ringer Add-On,"* February 21, 2000 issue.

Samuel Kerem, 1608 Gruenther Ave., Rockville, MD 20851; e-mail: skerem@netscape.net.

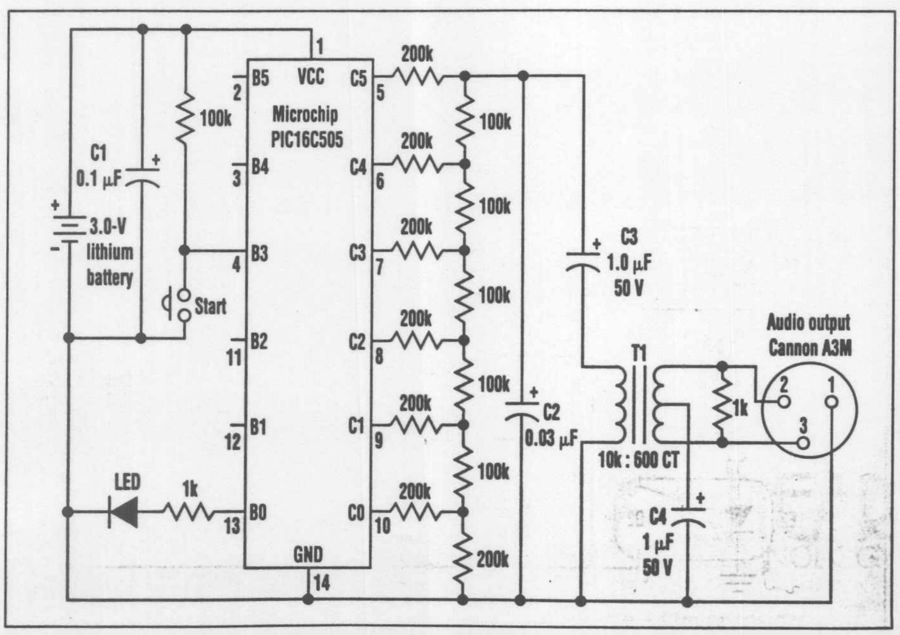
The idea: *"Comparator Features Symmetrical Thresholds,"* March 6, 2000 issue.

Low-Cost Microcontroller Acts As A Microphone Simulator

Jim Walker

812 North Rd., San Bernardino, CA 92404

If you have ever been involved in testing microphones while setting up a PA system, you have probably heard the phrase, "Testing, one, two, three" countless times. This idea describes a small, self-contained unit able to simulate spoken voice. It achieves this by driving a microphone input line with a sine wave at an appropriate level. Simply press the button and the module runs for five minutes. It then turns itself off using the PIC microcontroller's "sleep" mode.



This PIC-based waveform synthesizer can be adapted to produce almost any output frequency (or waveform). The unit turns itself off after a specified time period.

The sine wave is about 400 Hz, depending on the accuracy of the PIC's internal oscillator frequency. In this application, this is not at all critical. If greater accuracy is required, an external crystal can be used. Users can adapt this circuit to almost any other output frequency (or waveform), or amount of on-time. They simply have to change the delay variables in the program or the constants in the lookup table.

The simple circuitry is based on a PIC16C505 microcontroller that functions as a sine-wave lookup table. This device maintains an appropriate delay between points and drives a simple R-2R 6-bit digital-to-analog converter (DAC). Use of standard 1% resistors produces less than half of an LSB error. The sine wave has 72 stored values (at 5° increments). Therefore, the waveform is very smooth, with harmonics starting at about 30 kHz.

A single capacitor (C2) serves as a